REFRACTOMETER

The present specification is based upon Finnish Patent Application No. 20001733, the entire contents of which are incorporated by reference herein.

BACKGROUND

Field of the Invention

[0001] The invention relates to a refractometer and, more particularly, to a refractometer comprising an optical module arranged floatingly inside a housing structure for measuring the index of refraction of a process fluid.

Background Information

[0002] The operational principle of a refractometer has been known for over a hundred years. Today, refractometers are rather widely used on several different fields. The range of use of refractometers include food processing industry, wood processing industry, chemical industry and different researches in general.

[0003] The operational principle of a refractometer can be described by way of principle in the following manner. A refractometer measures the refractive index of the process fluid by means of total reflection generated at the interface between the optical window and the fluid. The illuminating beam from the source of light is directed at the interface between the optical window and the process fluid. Part of the illuminating beam is totally reflected from the fluid, whereas part of it is partly absorbed into the fluid. This results in an image in which the location of the light and dark areas depends totally on the critical angle of the total reflection, and thus on the refractive index of the process fluid.

[0004] The essential aspect of refractometer measuring is the

analysis of the image generated by the reflection of light. The objective of said image analysis is to find the critical angle of the total reflection, in other words the interface at which the light area of the image formed in the above-described manner changes over to a dark area.

[0005] As becomes obvious from the above-described aspects, the operation of a refractometer is based on very accurate angle measurement, because the critical angle of the total reflection is determined according to the refractive index of two materials. The problem with older refractometers has been angle variations of the optical window relative to the housing structure of the device. The angle variations are frequently due to the fact that the optical window in these devices is attached by means of a flexible sealing material. If the optical window is rigidly attached to the housing structure, the sealing material has to be very elastic, and thus certain materials with weak elasticity cannot be used. In several known refractometers, the optics and the light detector are rigidly attached to the housing, so that another problem is caused by an error in the angle measurement caused by the distortion of the housing structure.

[0006] To eliminate said drawbacks, a refractometer of a novel type has been provided, being disclosed in the Finnish patent application 980221. The advantage of this solution is that the optical window can be attached also by using a weakly elastic seal, such as Teflon, without the accuracy of the angle measurement suffering from this at all.

[0007] The refractometer described in the Finnish patent application 980221 functions extremely well in certain environments, but a problem is caused by measurement of aggressive fluids, for instance. Aggressive fluids include strong acids and bases, such as hydrochloric acid (HCl), hydrofluoric acid (HF), nitric acid (HNO_3) and sulfuric acid (H_2SO_4), as well as sodium (NaOH) and potassium (KOH) hydroxides and ammonia (NH_4OH). A plurality of acids and bases strongly corrode most of the structural metals, and alternative metals are expensive and difficult to be machined (such as

tantalum and zirconium). Further, problems are caused in measurement of less aggressive fluids in cases where impurities and metal ions are not desirable in the process fluid. In such cases, the process surfaces of tube systems and instruments must not contain any metal parts.

SUMMARY

[0008] An object of the invention is to provide a refractometer by means of which the drawbacks of the prior art can be eliminated. This has been achieved by means of a refractometer according to the invention. The refractometer according to the invention comprises an optical module arranged floatingly inside a housing structure, which module comprises an optical window to be positioned in a process fluid, and means for forming an illuminating beam and for directing it into the process fluid through the optical window and for directing back the part of the illuminating beam that is reflected from the process fluid, and further, means for watching the image formed in said manner, whereby the optical module is arranged to be supported against the housing structure by means of sealing arranged between the optical window and the housing structure. The housing structure part in contact with the process fluid against which the optical window is arranged to be supported via sealing is formed of a material that is chemically durable, mechanically rigid and durable and has good thermal conductivity.

[0009] An advantage of the invention is, above all, the applicability of the structure to the measurement of very different fluids. The solution is also simple, which enables the use of plastic materials, for example, in such parts that are not in contact with the process fluid or are not mechanically subjected to great stress, so that the manufacturing costs remain low.

BRIEF DESCRIPTION OF THE FIGURES

[0010] The invention will now be described in greater detail by means of a preferred application example illustrated in the attached drawing,

whereby

[0011] Figure 1 shows a principled diagrammatic view of the operation principle of a refractometer; and

[0012] Figure 2 shows a principled side view of a refractometer according to the invention.

DETAILED DESCRIPTION

[0013] Figure 1 shows a principled diagrammatic view of the operation principle of a refractometer. In Figure 1, reference numeral 1 denotes a source of light and reference numeral 2 denotes an optical window, which can be a prism, for example. Reference numeral 3 indicates a process fluid.

[0014] As mentioned above, a refractometer measures the refractive index of the process fluid by means of total reflection generated at the interface between the optical window 2 and the process fluid 3. The operation principle of a refractometer represents the prior art obvious to those skilled in the art, so that aspects related thereto are not described in more detail herein. In this connection, only the essential basic principle is explained.

[0015] An illuminating beam from the source of light 1 is directed at the interface between the optical window 2 and the process fluid. The illuminating beam is shown in Figure 1 in a principled manner by means of arrows. Part of the illuminating beam is totally reflected back from the process fluid 3, whereas part of it is partly absorbed into the fluid. This results in an image K, in which the location of the interface C between the light area A and the dark area B depends on the critical angle of the total reflection, and thus on the reflective index of the process fluid.

[0016] The operation of the refractometer is thus based on extremely accurate angle measurement, because the critical angle of the total reflection is determined according to reflective indices of two materials. As mentioned earlier, the problem with several refractometers known from the

prior art has frequently been angle variations of the optical window relative to the housing of the device, because the optical window is in several solutions attached to the housing by means of a flexible sealing material. The use of a flexible material as sealing has been due to the fact that if the optical window is rigidly attached to the housing, the sealing material has to be very elastic, and thus materials with weak elasticity cannot be used. In several known refractometers the optics and the light detector are rigidly attached to the housing, so that another problem has been caused by an error in the angle measurement due to the distortion of the housing.

[0017] In order to eliminate the above drawbacks, a solution has been provided in which a source of light 1, an optical window 2, means for directing the illuminating beam, and the light detector are arranged in a rigid optical module 4, which is shown in Figure 2. The optical module 4 is floatingly arranged to be supported by sealing 5 arranged between the housing structure and the optical window. The sealing can be cone sealing, for example, or it can form a spherical surface, etc. Since the optical module 4 floats supported by the sealing 5 relative to the housing structure or other mechanics of the device, external forces, such as forces generated by the flow of the process fluid, mechanical stress in the tube system, heat expansion and pressure, do not affect the accuracy of the measurement. Owing to the floating optical module 4, also materials with weak elasticity, such as Teflon, can be used in the sealing of the optical window, for instance a prism.

[0018] The optical module 4 is pressed against the sealing by means of appropriate spring members, whereby the compressive force is constant in all temperatures. Thus, the spring members together with the floating optical module compensate for the weak elasticity of certain sealing materials. The spring members are mounted in such a way that no process heat is conducted into the optical module through them. The spring members are not shown in Figure 2, but Finnish patent application 980221 is incorporated as reference herein, the structure being described in more detail

in said application.

[0019] The floating optical module 4 is in contact with the process fluid 3 and the tip 6 of the housing structure, i.e. the part of the housing structure that is in contact with the process, only through the optical window 2. The connector surface to the process and the tip of the housing structure is minimized to make thermal conduction more difficult. Between the optical window 2 and the tip 6 of the housing, there is sealing 5. The connector surface must allow small angle changes between the axis of the optical module and the axes of the tip. As mentioned above, the connector surface can be conical, for instance. Owing to the floating optical module, it is also easy to manufacture and maintain the device. The module can be tested as early as before the actual connection to the rest of the technique.

[0020] As mentioned above, the optical module 4 includes all optical elements. The optical module also includes a temperature sensor 8, because accurate concentration measurement also requires quick and accurate temperature measurement of the process fluid. The temperature sensor 8 is positioned in the vicinity of the tip of the housing in such a way that the heat contact in the direction of the tip and further to the process fluid is maximized. As regards the positioning of the temperature sensor 8, Finnish patent application 980221 is incorporated as reference herein, this aspect being described in more detail in said application. The process fluid 3 is conducted to the optical window by means of a flow vessel 7.

[0021] A thin (e.g. 0.25 mm) Teflon film between the cone surface of the optical window 2 at the tip of the optical module and the tip 6 of the housing structure functions as sealing 5, as observed earlier. Due to the weak elasticity of Teflon, the sealing force is produced by means of spring members, as mentioned above. The spring members press the optical module against the cone surface, whereby the conical sealing surface is subjected to the whole sealing force generated by the spring members, for instance approximately 500 Newtons. Said aspect imposes high mechanical

requirements on the material of the tip 6 of the housing structure.

[0022] The sealing material can be elastic, in which case the sealing force is generated by the material itself, and no external sealing force is required. The geometry of the sealing can also be different, such as an O-ring. In any case, the sealing surface is subjected to great force irrespective of the sealing material or the geometry of the sealing, so that the material used has to be mechanically rigid.

[0023] The positioning of the above-mentioned temperature sensor further imposes great additional requirements for the material of the tip 6 of the housing structure. The material must have as good thermal conductivity as possible, and still, it must be durable, since the temperature sensor cannot be in contact with the process fluid for chemical reasons, but the thermal conductivity characteristics must be good in any case. The tip part 6 of the housing structure, i.e. the part in contact with the process fluid 3 of the housing structure, against which the optical window 2 is arranged to be supported via the sealing 5, is formed of a material that is chemically durable, mechanically rigid and durable and has good thermal conductivity. The material can be a ceramic material, for instance. The use of sapphire has turned out to be particularly advantageous, as the manufacturing material of the above-mentioned part, since sapphire meets all the above requirements extremely well.

[0024] The tip part 6 of the housing structure in the example of Figure 1 is made of a sapphire disk having a conical sealing surface. The sapphire disk is further attached to other parts of the housing structure, which parts can also be metallic, since they are not in contact with the process fluid 3. It is to be noted that in practice, it is advantageous for different parts of the housing structure to be at least partly made of non-metallic material, for instance Teflon, also outside the process surface, since the process seal can leak. On the process side, the following materials can preferably be used. The tip part of the housing structure can be made of sapphire, and a spinel prism

can be used as the prism. A Teflon film can be used as a prism seal and a pre-fluoroelastomer as O-ring seals. The flow vessel can be made of a fluoro plastic material, for example.

[0025] Further, it is to be noted in relation to the invention that the tip part 6 of the housing structure, i.e. the sapphire disk, also functions, in a way, as a member decreasing the pressure stress, since a great sealing force directed at a small surface, i.e. the sealing 5, is directed at a greater surface by means of the rigid sapphire disk, whereby the counter-surface of said surface can be formed in a part made of less rigid material, such as a plastic material.

[0026] The above-described application example is by no means intended to restrict the invention, but the invention can be varied totally freely within the scope of the claims. Thus, it is obvious that the refractometer according to the invention and the details thereof do not have to be exactly like the ones shown in the figure, but other solutions are also feasible.